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Search for cluster decay of ^{114}Ba

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Abstract. A search for the ^{12}C decay of ^{114}Ba produced in the ^{58}Ni(^{58}Ni,2n) reaction was performed by using polycarbonate track detectors. Assuming the total half-life of ^{114}Ba to be $\gtrsim$0.1 s, the lower limit $T_c \geq 10^3$ s for the partial ^{12}C-decay half-life was established.

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1. Introduction

First theoretical predictions of nuclear lifetimes for cluster radioactivities in the new region above closed shells Z=50, N=50 were made by Greiner et al. [1,2]. In their calculations, the most favourable case here is predicted to be the decay of the very neutron-deficient isotope ^{114}Ba by spontaneous ^{12}C emission leading to the daughter nucleus ^{102}Sn. As yet, the isotope ^{114}Ba has not been identified. Ground-state decay properties expected for ^{114}Ba sensitively depend on its unknown mass value for which different mass models [3] yield results varying by more than 2 MeV. This causes large variations of the partial half-life T_c predicted for the ^{12}C decay of ^{114}Ba (Fig.1). Even more dramatic uncertainties arise for the partial α-decay half-life of this nucleus. As for EC(β^+) decay of ^{114}Ba, from systematics [5,6] its partial half-life is expected to be in the range of 0.1 to 1 s. If we assume the total ^{114}Ba half-life to be , say, 0.1 s, then the branching ratio b_c for the ^{12}C decay of ^{114}Ba turns out to be of the order of 10^{-10}. It is clear that experiments on probing such small branching ratios are virtually precluded because of insufficient rates of the ^{114}Ba production by any feasible means.

However, more recent lifetime calculations performed for the ^{12}C decay of ^{114}Ba by Kadmensky et al. [4] have led to T_c values which are 10^6–10^7 times lower compared to estimations of [1,2] (see Fig. 1). This brings predicted branching ratios b_c to a detectable level. It is noteworthy that calculations of [4] and those of [1,2] give identical results for α decay of ^{114}Ba.

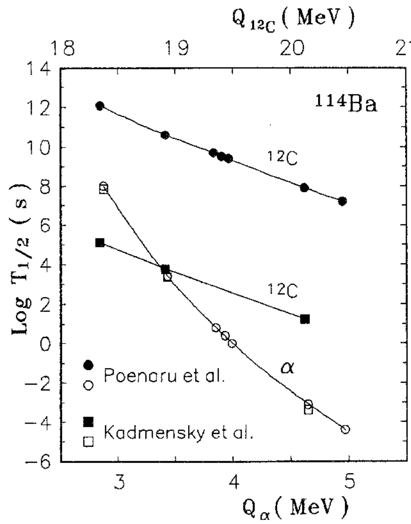

Fig. 1. Partial half-lives for α and ^{12}C decays of ^{114}Ba predicted by Poenaru et al. [2] and Kadmensky et al. [4] as functions of the released energies Q_α and $Q_{^{12}C}$

2. Experimental technique

Guided by the above predictions, we carried out first experiments to search for carbon radioactivity of ^{114}Ba. For the production of ^{114}Ba, we employed the reaction ^{58}Ni(^{58}Ni,2n). The irradiations were performed at the Dubna U400 cyclotron by using the wheel technique outlined in Fig. 2. A beam of ^{58}Ni projectiles with an incident energy of 280 MeV struck tangentially the lateral surface of a cooled copper cylinder onto which 3.5 mg/cm^2 of natural nickel were electrodeposited. This cylindrical target (serving simultaneously as a recoil catcher) rotated at a rate of 10 rev/s which allowed efficient searches for decays with $T_{1/2} \gtrsim 10$ ms. To detect ^{12}C clusters, 200-μm polycarbonate films were arranged all around the cylindrical target except for the beam input zone. The polycarbonate track detectors were calibrated by using beams of ^{12}C projectiles from the U400 cyclotron. The calibration was made in the ^{12}C energy range of 7 to 24 MeV.

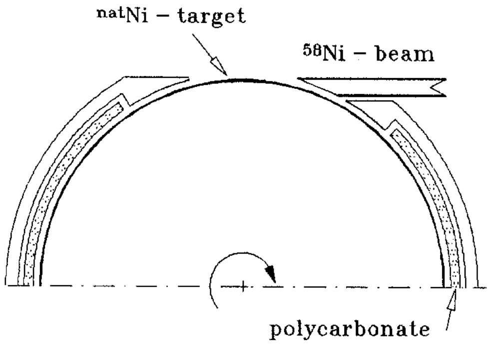

Fig. 2. Scheme of the experiment

In searching for the ^{12}C decay of ^{114}Ba, the main background was due to tracks from ^{12}C recoils produced in polycarbonate by fast neutrons accompanying the ^{58}Ni beam. Therefore the back side of the polycarbonate detectors (see Fig. 2) was carefully scanned as well, which allowed us to estimate the background and compare it with the track pattern revealed on the front polycarbonate side viewing the target surface.

3. Results and discussion

The ^{12}C range spectra resulting from the ^{nat}Ni+^{58}Ni bombardment with a total ^{58}Ni beam dose of 3.5×10^{17} are shown in Fig. 3. No tracks with the length larger than 11μm were revealed on the back side of the polycarbonate detectors. On the front side, however, some ten tracks were found to have a length exceeding that of most of the background tracks produced by ^{12}C recoils. From the viewpoint of ranges, these longer tracks might be due to ^{12}C decays of ^{114}Ba. The time distribution of the corresponding decay events would then be roughly uniform within the interval of $\approx$0.1 s. However, taking into account the low number of relevant events as well as the presence of the considerable background, so far we consider it reasonable to set an upper limit of the effect in question.

According to statistical-model calculations, the production cross section of ^{114}Ba in the ^{58}Ni+^{58}Ni reaction is expected to be of the order of 1 μb. Then, assuming for the width of the excitation function a FWHM value of 20 MeV, we obtain an estimate of 2×10^6 for the total number of the ^{114}Ba nuclei produced. The detection efficiency of ^{12}C decays is estimated to be about 0.07. This value includes a factor of 0.5 for detection in 2π geometry, a factor of 0.7 due to losses in the beam input zone, a factor of $\approx$0.4 reflecting the fact that the track length determination is possible

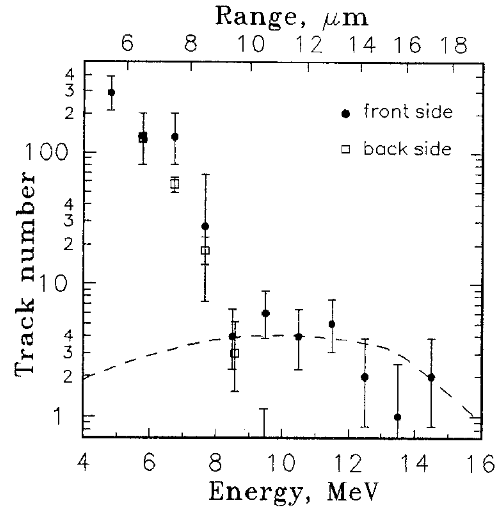

Fig. 3. Range (energy) spectra from ^{12}C track measurements on the front and back sides of the polycarbonate detectors. *Dashed line* shows the calculated energy spectrum of ^{12}C clusters from the decay of ^{114}Ba recoils implanted in the catcher

only for those ^{12}C clusters which escape the catcher in a certain solid angle, and, finally, a factor of $\approx$0.5 allowing for losses of low-energy ^{12}C clusters in the background range (see Fig. 3). All in all, it follows from our data that $b_c \leq 10^{-4}$ for the ^{12}C decay of ^{114}Ba. Assuming the total ^{114}Ba half-life to be $\gtrsim$0.1 s, we obtain the lower limit $T_c \geq 10^3$ s which can be compared with the T_c predictions shown in Fig. 1. Obtaining more positive conclusions about the ^{12}C decay of ^{114}Ba represents a challenge for future experiments.

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